

# **Environmental Analysis of Oceanographic Effects on SHAREM 126 Exercise Systems Performance**

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## **LONG-TERM GOALS**

Recent reports issued by N84 ASW Requirements Office and SWDG Cross SHAREM Analysis <sup>1</sup> point to a need to better understand and quantify the effects of the shallow water-littoral environment on system performance. Past analyses by NRL and others give some indication as to the sensitivity to environmental factors (e.g. internal waves, solitons, fronts, eddies, and other temporally/spatially-dependent effects) that can be expected to affect system performance. A study of the recent SHAREM 126 experiences can be used to explain/understand system performance and to exploit (i.e., environmentally adapt to) the environment for better performance.

In conjunction with system performance sensitivity is the aspect of environmental sampling to improve prediction capability, and the assimilation of that data into dynamic oceanic prediction models. With the advent of more capable, and more expensive environmental sampling buoys, it is necessary for the acoustic system prediction community to make intelligent decisions on where to place a small number of capable environmental sensors that will provide the 'best' environmental input to the prediction models.

## **OBJECTIVES**

Analyze SHAREM 126 exercise experience with the emphasis on identifying and understanding the physical processes, both oceanographic and acoustic, that are the causal factors behind many system performance anomalies that have been observed. Evaluate the issue of environmental sampling when using a limited number of sampling devices to optimize acoustic system performance prediction.

## **APPROACH**

Compile as much environmental / acoustic data and system documentation as possible. Using Navy Standard and Research models, predict, compare and study measured acoustic results. Combine these model outputs with systems models to evaluate system performance. Utilize these model results to evaluate errors induced. The environmental sampling is assumed to be the equivalent of temperature, and or temperature and chlorinity, the geoacoustic environment (that is geological structure of the sea floor that impacts bottom interaction) is assumed to be known.

## **WORK COMPLETED**

SHAREM 126 was conducted by the Surface Warfare Development Group (SWDG) in the East Sea of Korea from 12-18 September 1998. The Naval Oceanographic Office collected oceanographic and

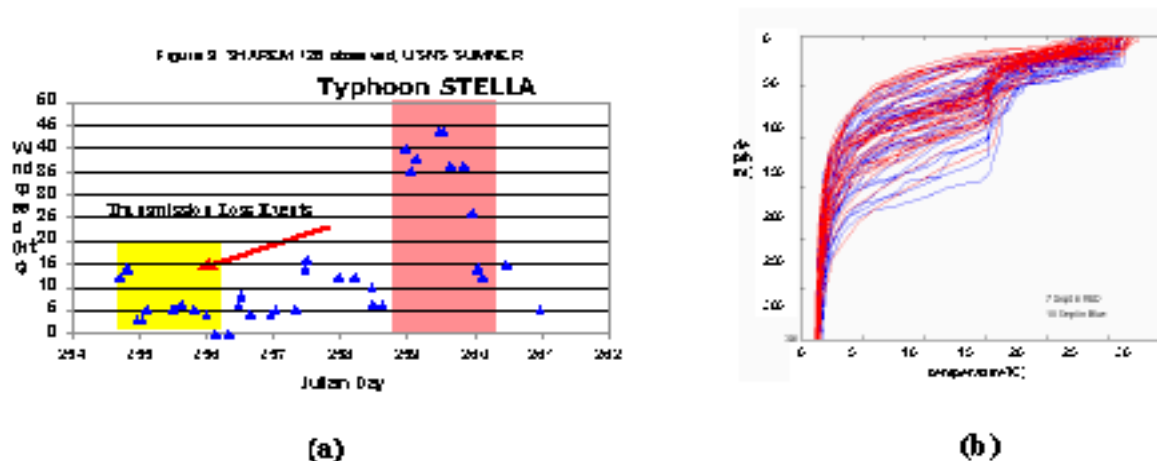
acoustic data to characterize the acoustic environment during this exercise <sub>2</sub>. These data include physical oceanography, bottom characteristics, bioluminescence, and acoustic data. The following table lists data compiled from various sources for this study. These data along with Navy Standard and research models and databases were used to investigate the environmental impact on acoustic performance. Environmental findings associated with SHAREM 126 and the related Distant Thunder May 1998 Engineering test were summarized for application to sampling strategy. The problem of prediction error when using an incorrect sound speed representation was then evaluated using model results. Comparisons are made for constant depth with range independent sound speed, sloping bottom with range independent sound speed and sloping bottom for range dependent sound speed.

	Category	Description	Source	Exercise
1	Acoustic	Transmission Loss	NAVO	SH-126
2	Oceanographic	AXBTs	NAVO	SH-126
3	Oceanographic	Btm Cores	NAVO	SH-126
4	Environmental	Ambient Noise	NAVO	SH-126
5	Oceanographic	Bathymetric	NRL -TOWAN	SH-126
6	Oceanographic	Geoacoustic	NRL- TOWAN	SH-126
7	Documentation	basic Data Report for SHAREM 126	NAVO	SH-126
8	Oceanographic	MODAS	NRL / NAVO	SH-126
9	Documentation	Cross-SHAREM Report	SWDG	multiple

*Table 1. Data collected from various sources for SHAREM 126 study.*

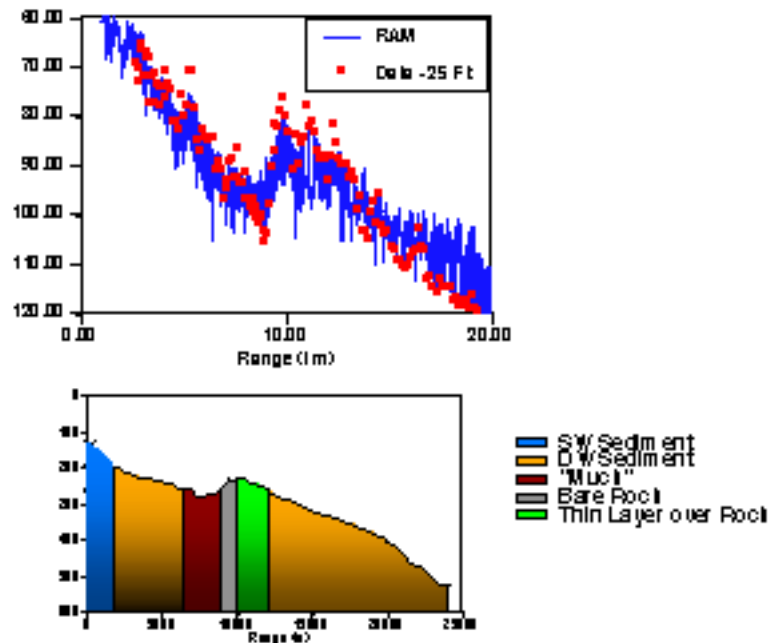
## RESULTS

A significant environmental event during SHAREM 126 was Typhoon Stella. It passed very near the exercise area and resulted in winds up to 45 kts. at the NAVOCEANO measurement site. AXBT and XBT data collected prior to and following this event, show large differences in the upper portion of the water column after the storm had passed (fig. 1). The sea surface had clearly mixed with subsurface waters resulting a cooler, nearly isothermal layer 30-40 m thick.



*Figure 1 a) wind speeds during SHAREM 126 and b) water column temperature profiles before and after typhoon.*

Propagation measurements were made from two sites during the exercise. These measurements along with water column and sediment sound speed measurements were used to ground truth our acoustic and geoacoustic models. The figure below shows one example of a propagation track over a ridged bathymetric feature. The geoacoustic model developed earlier by Jim Fulford<sub>3</sub> was ground-truthed with core measurements. This geoacoustic model and high resolution bathymetric data were used to validate our acoustic modeling capabilities with the RAM propagation model.

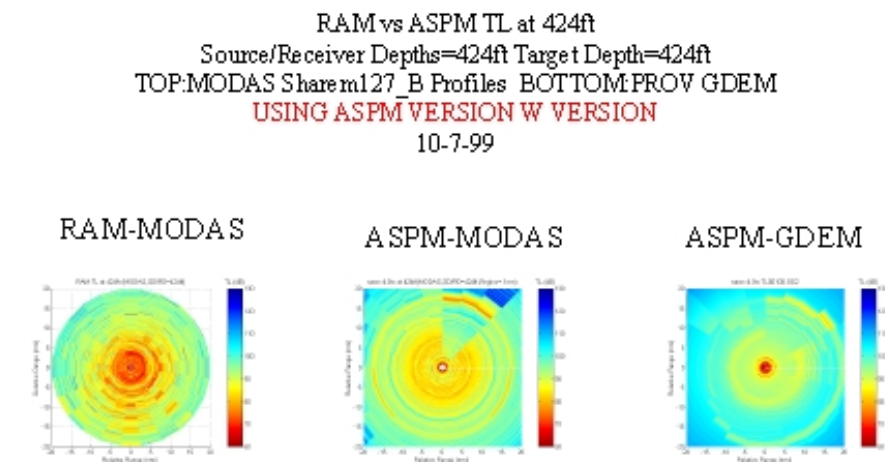


**Figure 2. Acoustic data comparison with model (RAM) and geoacoustic model with bathymetry.**

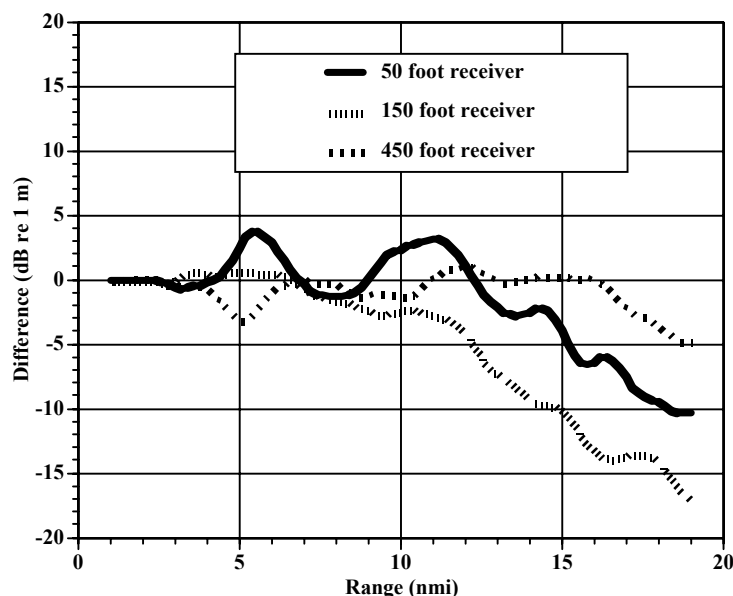
Once the acoustic modeling was validated, the system model (ASPM) was used to compare with actual system performance. Modeling results compared well with measurements when high resolution bathymetric data, MODAS with insitu measurements, and Fulford's geoacoustic model were used. However, modeling performance dropped off significantly when archived sound speed data (GDEM) was used to predict transmission loss and signal excess. The Figure 3 shows some initial results of using RAM and ASPM with MODAS and ASPM with GDEM.

For sampling strategy, the errors in prediction arise from either misrepresenting the range dependency of the environment, or the environment at the sensor location. The errors in range dependency are represented by simple single realization calculations. The error in the local environment was picked to be representative of a MODAS prediction error. Figure 4 shows calculation results using range dependent sound speed. There is little difference between different receiver depth curves or between these curves and those for the range dependent case in the first 5 nmi. Sampling then should be on that range scale and satellite imagery should provide locations. Difficulties with the approach of using satellite imagery for determining environmental sensor drop locations are limits from cloud cover and determining computationally from the imagery where to drop the sensor. That is whether to drop the sensor at the interface between the colors indicating contact between two water masses, or somewhere to the east, or west of the contact line. The CompuServe Graphics Interchange Format (GIF) is

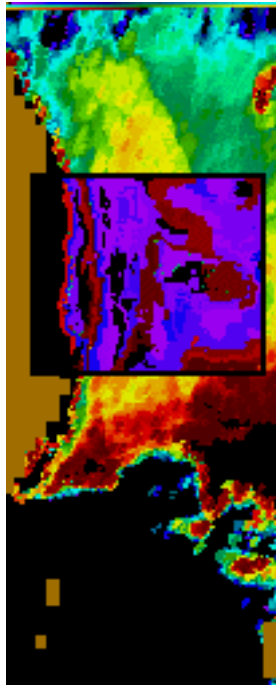
essentially a losslessly compressed 8 bit file, which can be converted into a  $N \times M$  matrix of color values for sea surface temperature at grid a location. One can convert those colors to numerical values that can then be used to determine the gradients of the sea surface temperature to delineate fronts. Using finite differencing techniques, the x and y partial derivatives are computed, and the derivative turned into a GIF. The derivative of the Korean Coastal Front map is shown in figure 5.



**Figure 3. Comparison of RAM and ASPM model results using MODAS sound speed profiles and ASPM using GDEM sound speed profiles.**



**Figure 4. Source on continental slope looking shoreward for range dependent sound speed.**



*Figure 5. Derivatives from GIF file color mapping used to numerically define temperature high gradient regions.*

## **IMPACT/APPLICATIONS**

Implications are that historical profiles are very deficient in portraying system performance in the shallow water environment. However; it appears likely that if the modeling assumptions are correct, then the most important place to know the sound speed is the sensor location. The rms error from the ensemble calculation was approximately 7 dB for cross duct propagation (that is source depth to the near surface receiver) at a range of 5 nmi, while the maximum error for misrepresenting the sound speed as range independent was less than 7 dB at a range of 5 nmi. This suggests that collocation of environmental and acoustic sensor may be an optimal arrangement.

## **TRANSITIONS**

The work begun here will be followed with a more detailed study in the project “Environmental Effects in Naval Sonar Signal Processing and Performance”. In this project we will focus on four SHAREM exercises conducted in this East Sea of Korea area with reconstruction data provided by SWDG to better understand and explain ASW system performance.

Work on sampling strategy will be applied to design criteria and requirements for new sensors being developed.

## **RELATED PROJECTS**

1 - Littoral Warfare Advanced Development (ONR CODE 321 US) CDR Scott Tilden, program manager is supporting system development with a comprehensive set of environmental and environmental acoustic measurements to document and quantify environmental impact and variability.

2- Environmental Acoustic Support Plan for 1999 Distant Thunder Program (ONR Code 321 US), Nancy Harned, Program Manager is supporting the investigation of the dynamic environmental conditions in the littoral region off the east coast of Korea and the East China Sea where the Navy is tasked to implement multistatic Distant Thunder (DT) program technologies and transition this capability to the Navy.

## **REFERENCES**

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